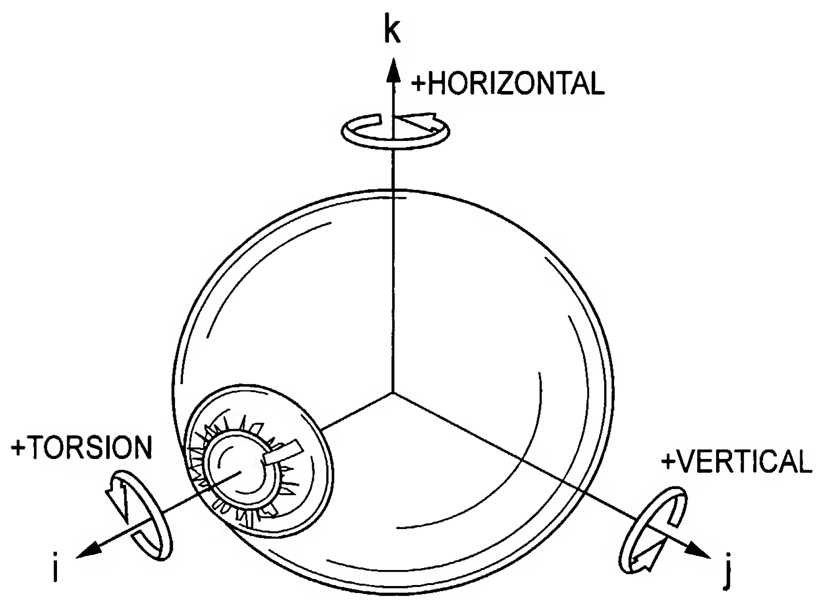


FIG. 1

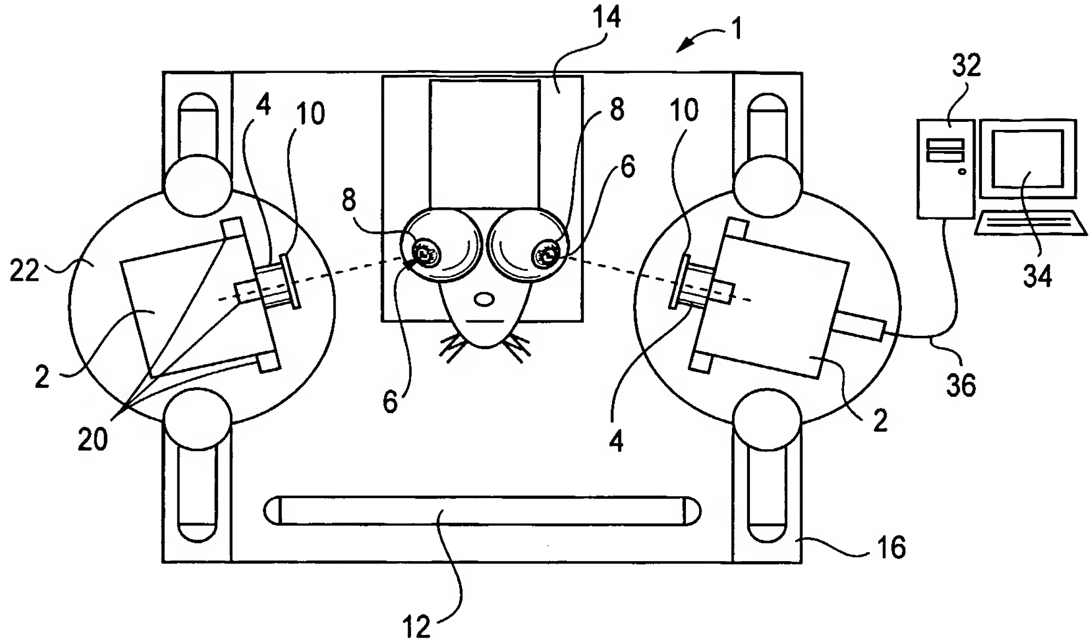

14
1
32
4
10
8
10
6
8
22
34
2
6
20
4
36
2
16
12

FIG. 2a

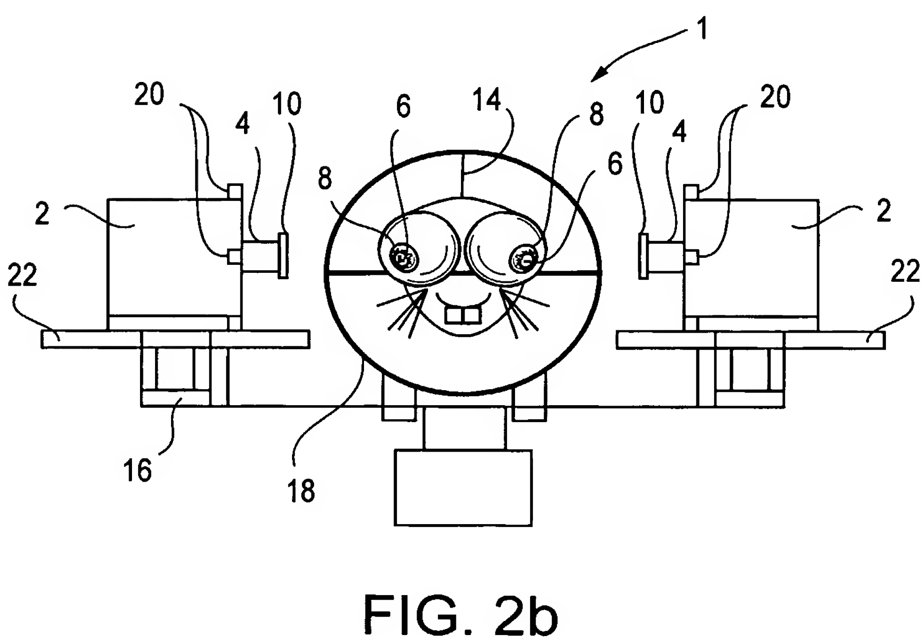

1
20
10
4
6
14
8
10
20
4
8
6
2
2
22
22
16
18

FIG. 2b

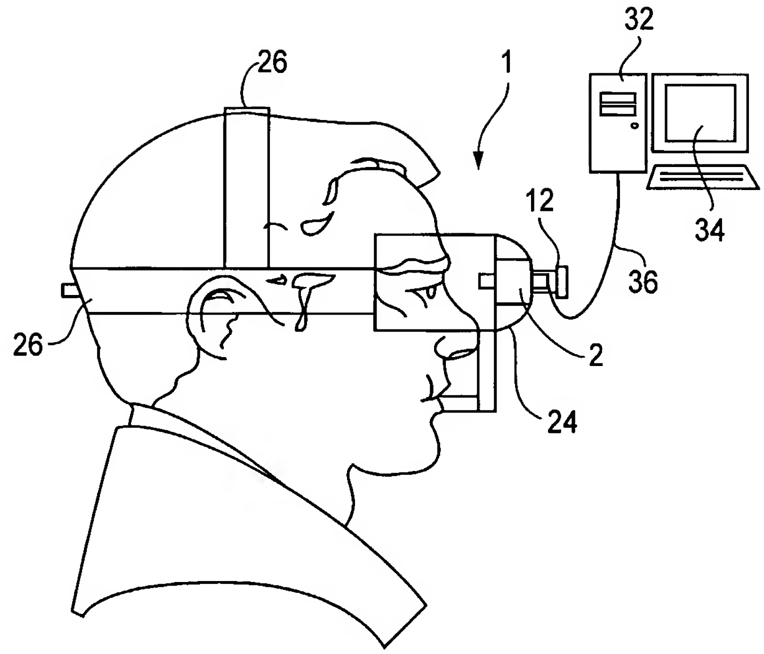


FIG. 3a

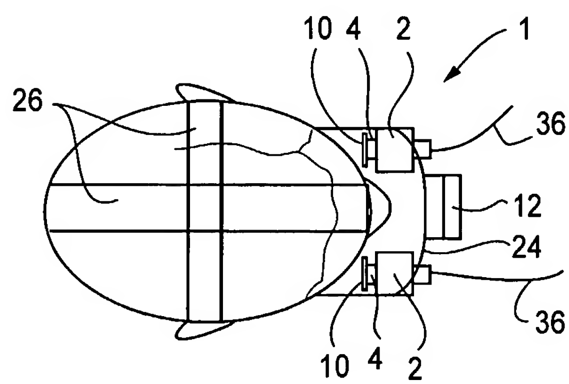


FIG. 3b

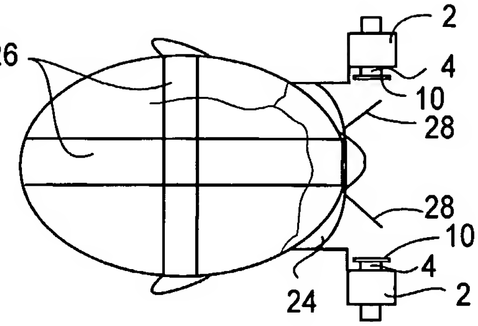


FIG. 4

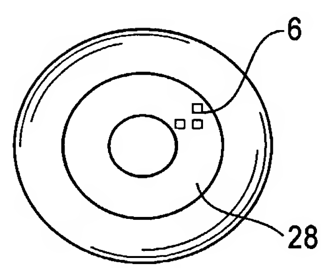
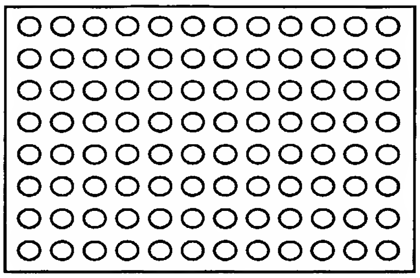


FIG. 5

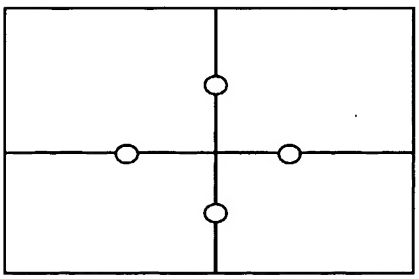
FIG. 6a

STEPS IN CALCULATING EYE POSITION USING VIDEO OCULOGRAPHY



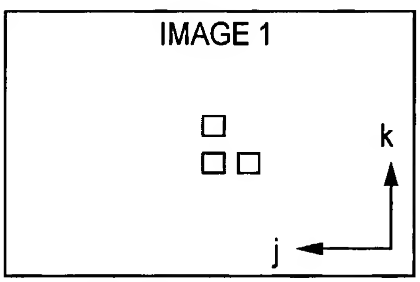
STEP 1

THE CAMERA AND LENS IS CALIBRATED USING DOTS EVENLY SPACED BY A KNOWN DISTANCE. THIS ENSURES AN UNDISTORTED VIDEO IMAGE.



STEP 2

THE REFLECTIONS OF 4 WHITE LIGHT LEDS EQUALLY POSITIONED FROM THE CAMERA'S OPTIC AXIS ARE USED TO CENTER THE EYE ON THE VIDEO IMAGE.



STEP 3

THE MARKER ARRAY IS POSITIONED ON THE EYE AND ILLUMINATED.

STEP 4

THE KNOWN DISTANCE BETWEEN THE MARKERS IS USED TO CALIBRATE THE PIXEL SIZE IN MILLIMETERS.

STEP 5

THE CENTER OF THE VIDEO IMAGE IS DEFINED AS THE ORIGIN (0, 0, 0). USING A CENTER OF MASS ALGORITHM THE TWO-DIMENSIONAL COORDINATE (j,k) OF THE CENTER OF EACH MARKER IS DETERMINED.

STEP 6

USING THE KNOWN RADIUS OF THE EYE, AND ASSUMING THAT THE EYE IS A SPHERE, THE POSITION OF EACH MARKER ALONG THE CAMERA'S OPTIC AXIS, i, IS CALCULATED USING THE FORMULA BELOW. THUS THE THREE-DIMENSIONAL POSITION (i,j,k) OF EACH MARKER WITH RESPECT TO THE ORIGIN IS KNOWN.

FIG. 6b

$$i = \sqrt{((eye\_radius\_in\_pixels)^2 - (j^2+k^2))}$$

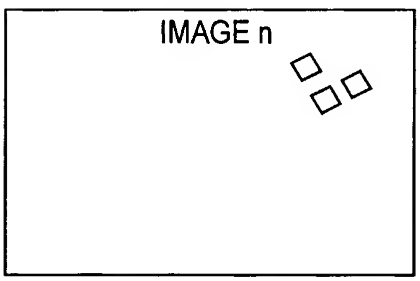
STEP 7

ONE IMAGE IS DEFINED AS THE REFERENCE IMAGE. FOR EXAMPLE "IMAGE 1" ABOVE. THE THREE-DIMENSIONAL COORDINATES OF EACH MARKER IN THIS IMAGE DEFINE THE REFERENCE OR ZERO POSITION OF THE MARKER ARRAY (AND EYE) AND ARE USED TO CONSTRUCT THE REFERENCE POSITION ROTATION MATRIX BELOW.

$$R = \begin{bmatrix} i_0 & i_1 & i_2 \\ j_0 & j_1 & j_2 \\ k_0 & k_1 & k_2 \end{bmatrix}_{REFERENCE}$$

STEP8

THE THREE MARKERS IN EACH IMAGE ARE IDENTIFIED AS MARKER 0, MARKER1 OR MARKER 2. A LEAST SQUARES ALGORITHM IS USED TO ENSURE THAT EACH MARKER IS CORRECTLY IDENTIFIED AFTER TRANSIENT LOSS OF MARKER TRACKING.



STEP9

FOR EACH IMAGE THE THREE-DIMENSIONAL POSITION OF EACH MARKER IS CALCULATED AND USED TO CONSTRUCT A CURRENT POSITION ROTATION MATRIX .

$$R = \begin{bmatrix} i_0 & i_1 & i_2 \\ j_0 & j_1 & j_2 \\ k_0 & k_1 & k_2 \end{bmatrix}_{CURRENT}$$

STEP 10

EYE POSITION (ROTATION MATRIX) IS DEFINED AS THE THREE-DIMENSIONAL ROTATION REQUIRED TO MOVE THE MARKER ARRAY (THREE MARKERS) FROM THE REFERENCE POSITION TO THE CURRENT POSITION.

$$\mathcal{R} = \begin{bmatrix} i_0 & i_1 & i_2 \\ j_0 & j_1 & j_2 \\ k_0 & k_1 & k_2 \end{bmatrix}_{CURRENT} * \begin{bmatrix} i_0 & i_1 & i_2 \\ j_0 & j_1 & j_2 \\ k_0 & k_1 & k_2 \end{bmatrix}^{-1}_{REFERENCE}$$

STEP 11

EULER ANGLES, FICK ANGLES, HELIOHOLTZ ANGELES, ROTATION VECTORS OR QUATERNIONS CAN BE CALCULATED FROM THE EYE ROTATIONMATRIX TO DESCRIBE EYE POSITION.